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UPPER CRETACEOUS - LOWER PALEOGENE FORAMINIFERAL PALEOECOLOGY OF NORTH AND SOUTHWEST SINAI AREAS, EGYPT

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The planktic and benthic foraminifers of the Upper Cretaceous - Lower Paleogene successions exposed at north and southwest Sinai in Egypt have been studied to contribute in the understanding of the paleoecology, paleobathymetry and tectonic history of these sedimentary sequences. These sediments are subdivided into three rock units (from older to younger): Sudr, Esna and Thebes Formations. According to its planktic foraminiferal content the succession is subdivided into thirteen biozones.

The studied, succession is divided into five and nine ecozones in north and southwest Sinai areas respectively (after their foraminiferal content). The environment of each ecozone is deduced. These environments point to bathyal depths for the Sudr Formation and an outer neritic to bathyal environment for the Esna Formation in southwest Sinai and littoral to middle neritic one in north Sinai. It indicates, also, that the Thebes Formation was deposited in outer neritic conditions in southwest Sinai and in middle neritic conditions in north Sinai. A proposed paleobathymetric curve is presented. The interpretation of this curve helped to deduce the tectonic history of the Upper Cretaceous - Lower Paleogene sediments in the studied areas.

Key Words:
Cretaceous, Paleogene, Foraminifera, Paleoecology, Paleobathymetry, Ecozone.

INTRODUCTION

The present work deals with the foraminiferal paleoecology of the Upper Cretaceous - Lower Paleogene succession of the north and southwest Sinai areas, Egypt. This study is based mainly on samples collected from four outcrop sections. Two sections from north Sinai area, El Hassana section (latitude 30' 30' N and longitude 33' 45' E) and Gebel Yellg section (latitude 30' 20' N and longitude 30' 35' E). The other two sections from the southwest Sinai area are: Wadi Feiran section (latitude 28' 40' N and longitude 330 28') and Gebel Matulla section (latitude 29' 5' N and longitude 33' 10' E), see Figure (1).

The sequence of the studied sections is subdivided into three rock units, these are arranged chronologically as follows from base to top:

1- Upper part of the **Sudr Formation,** it is of Maastrichtian age and consists of white to grey, bedded chalky limestone, partly marly and grading into creamy marlstone in its lower part. It underlies conformably the Esna Formation.
2- **Esna Formation,** is composed of laminated green and grey marl and shale intercalated with several argillaceous and chalky limestone ledges. Its age ranges from the Late Maastrichtian to the Early Eocene. It overlies conformably the Sudr

Formation and underlies conformably the Thebes Formation.

3- **Thebes Formation,** it consists of massive limestone intercalated with chert bands and nodules. It overlies the Esna Formation and underlies the Appolonia Formation of Early Eocene age.

The foraminiferal fauna separated from the studied 249 samples comprises 58 planktic foraminiferal species belonging to 21 genera (Fig. 2) and 116 benthic species belonging to 53 genera (Fig. 3,4). According to this fauna the studied succession has been subdivided into 13 biozones **[1]**.

Accounts on the paleoecology of similar sediments in Egypt are given by **[1-21]** and others.

PALEOECOLOGIC INDICATORS

The paleoecologic indicators which are used in the present study include:

1- Frequency:

It is considered here as the average number of individuals of a given foraminiferal species in a fixed volume of sediment in each sample **[22]**.

2- Planktic Foraminiferal Groups:

The identified planktic foraminiferal taxa are subdivided into three groups (heterohelicidae or uncoiled planktics, unkeeled and keeled or coiled planktics) **[23-24]**. Fig. (5) gives lists of the genera belonging to each group.

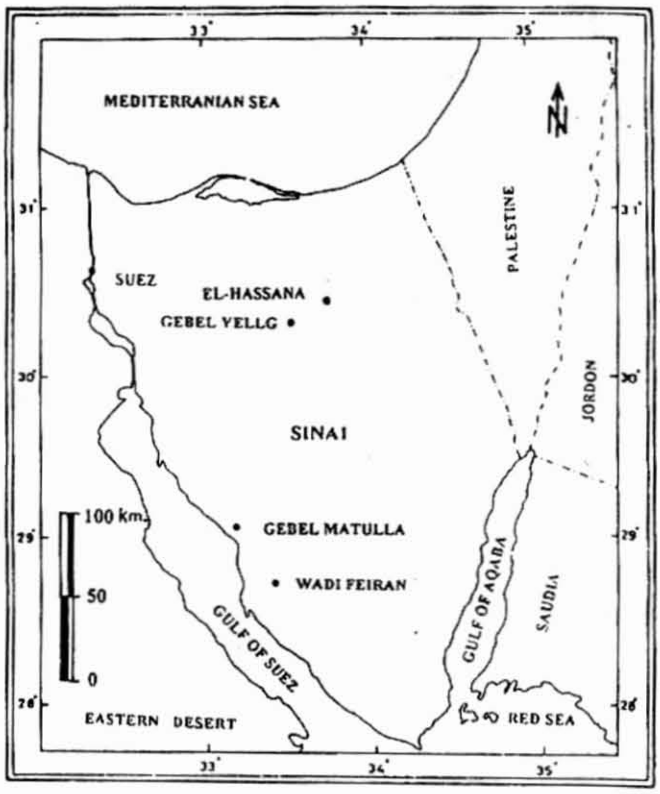

Figure 1: Location map of the studied sections in north and southwest Sinai areas, Egypt.

3- Benthic Foraminiferal Groups:

The identified benthic foraminiferal genera are arranged into five ecologically significant groups. They are arenaceous, millolidae, nodosariidae, buliminidae and rotaliidae **[24-26]**. Fig. (5) shows the genera belonging to each of the mentioned five groups.

4- Diversity:

It is expressed here as the total number of species in a sample or at any one time interval **[23, 27, 28]**.

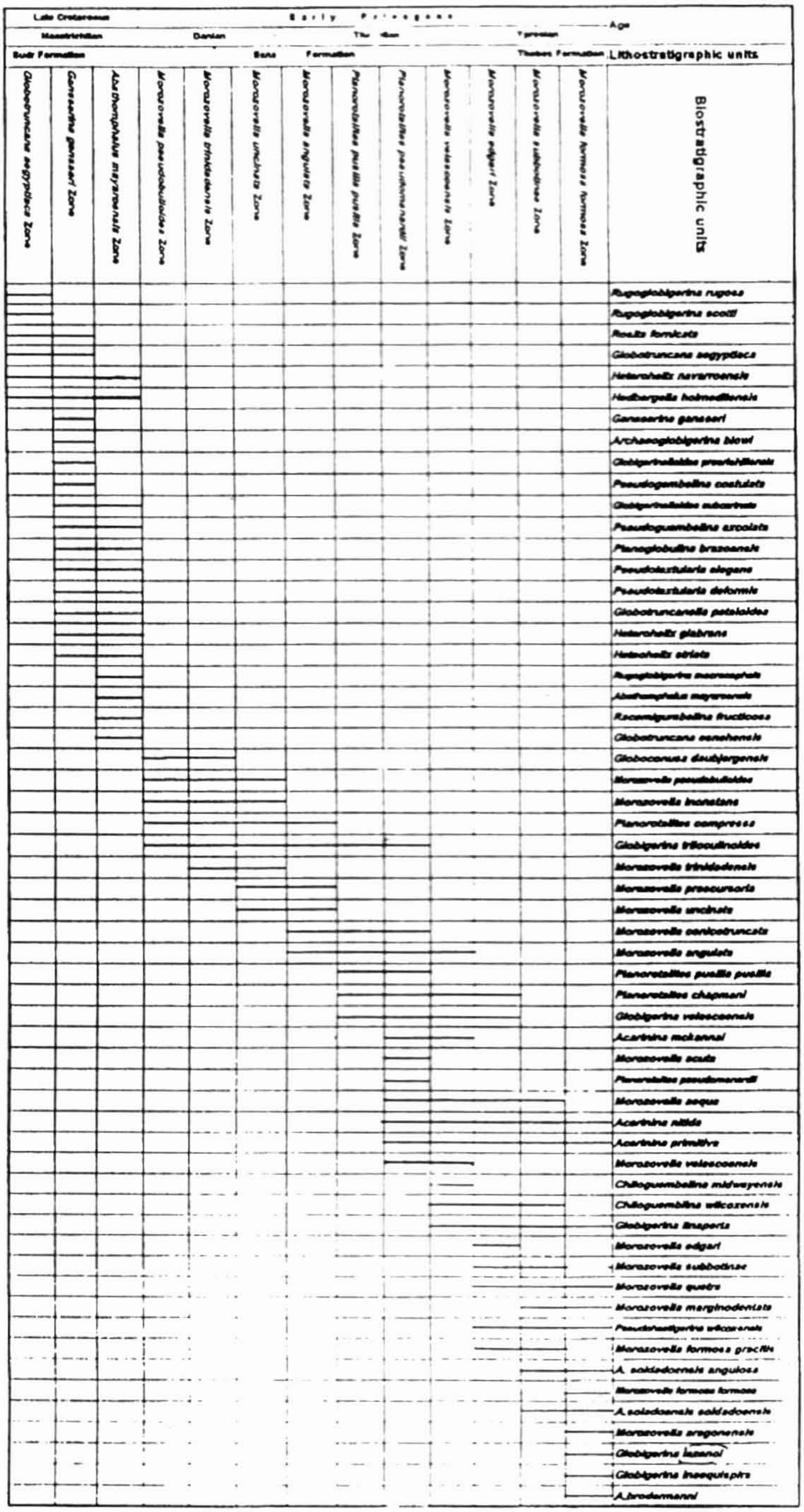

Fig. (2) Composite stratigraphic range chart of the identified Upper Cretaceaus – Lower Paleogene plankitc foraminiferal species recognized in the studied areas (not to scale).

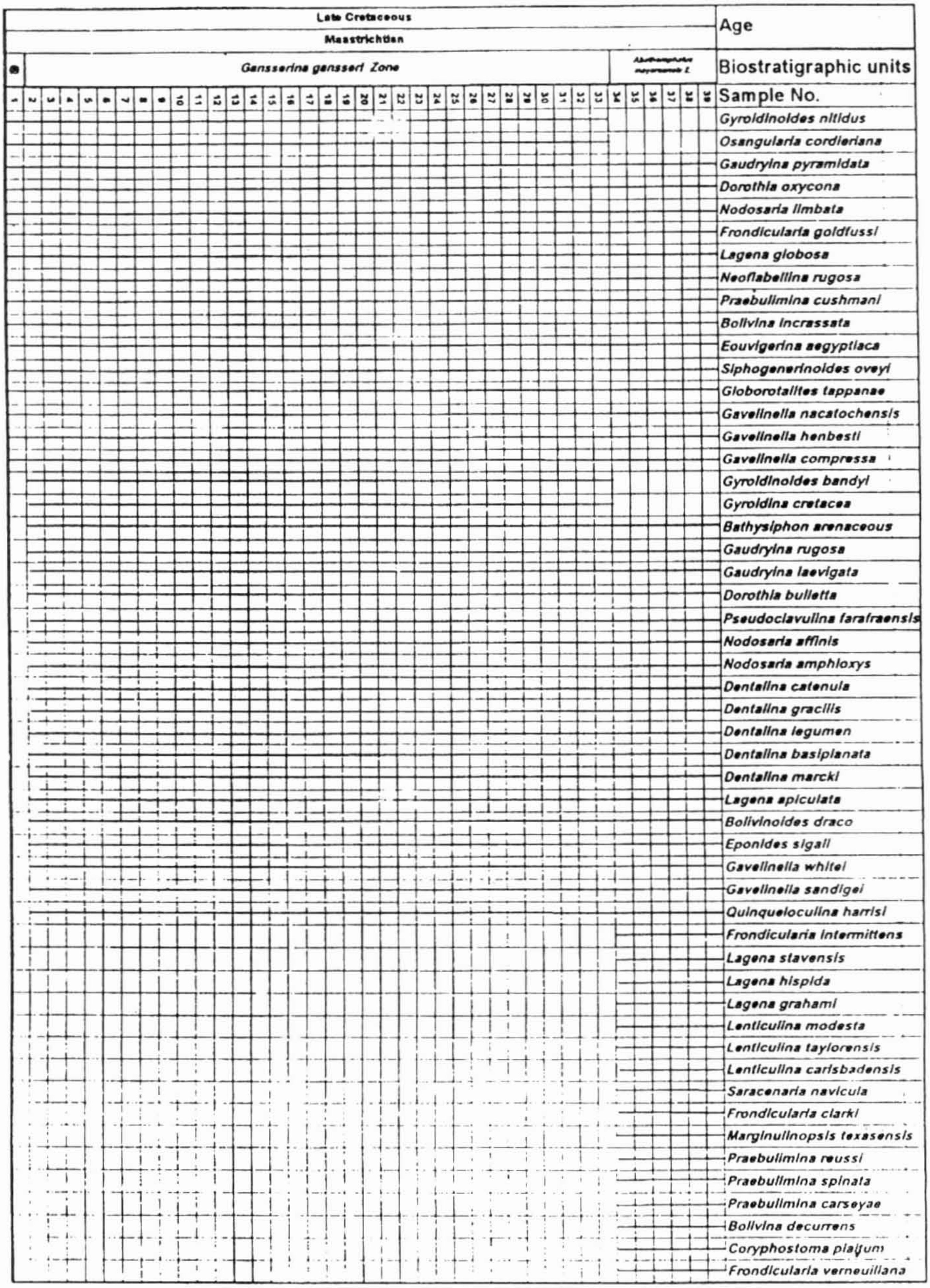

Fig. (3) Composite stratigraphic range chart of the identified Upper Cretaceous benthic foraminiferal species recognized in the studied areas (not to scale).

@ = *Globotruncana aegyptiaca* Zone.

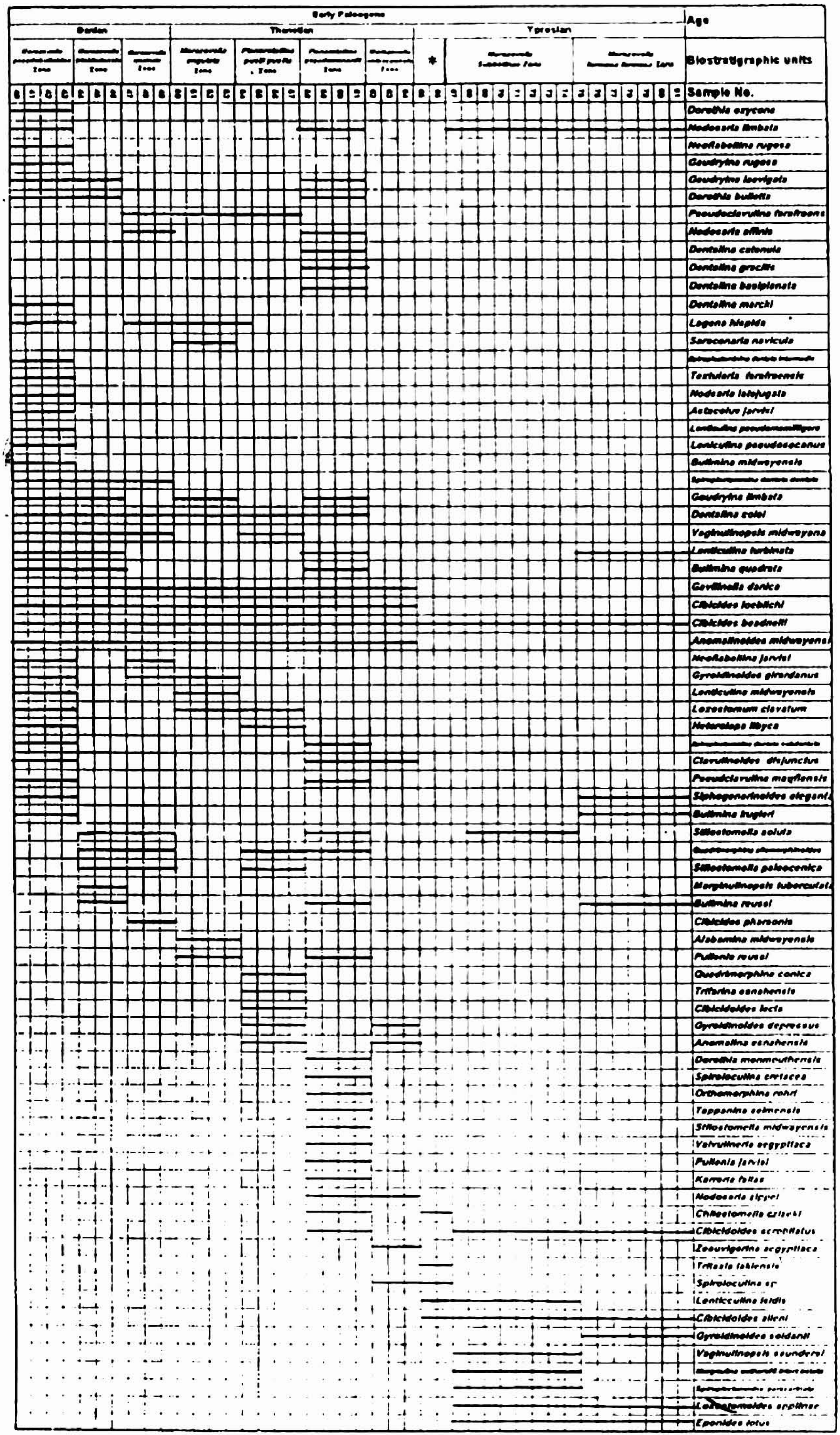

Fig. (4) Composite stratigraphic range chart of the identified Lower Paleogene benthic foraminiferal species recognized in the studied areas (not to scale).

* *Morozovella edgari* Zone.

Foraminiferal group		***Genera***	***Environment***
Planktic	Heterohelicidae	*Heterohelix, Pseudoguembelina, Planoglobulina, Pseudotextularia, Racemiguembelina, Chiloguembelina.*	Shallow marine
	Unkeeled	*Rugoglobigerian, Hedbergella, Archaeoglobigerina, Globigerinelloides, Globotruncanella, Globoconusa, Planorotalites, Globigerina, Acarinina, Pseudohastigerina.*	Intermediate marine
	Keeled	*Rosita, Globotruncana, Gansserina, Abathomphalus, Morozovella.*	Deep marine
Benthic	Arenaceous	*Bathysiphon, Gaudryina, Dorothia, Pseudoclavulin, Spiroplectammina, Clavulinoides, Textularia, Tritaxia, Vulvulina.*	Littoral and shallow marine
	Miliolidae	*Quinqueloculina, Spiroloculina.*	Littoral and shallow marine
	Nodosariidae	*Nodosaria, Frondicularia, Lagena, Dentalina, Lenticulina, Saracenaria, Marginulinopsis, Neoflabellina, Astacolus, Vaginulinopsis, Orthomorphina, Marginullina*	Intermediate to deep marine
	Buliminidae	*Proebulimina, Bolivina, Bolivinoides, Eouvigerina, Siphogenerinoides, Coryphostoma, Loxostomum, Bulimina, Tappanina, Stillostomella, Quadrimorphina, Trifarina, Zeauvigerina, Loxostomoides.*	Intermediate to deep marine
	Rotaliidae	*Gyroidinoides, Gyroidina, Osangularia, Eponides, Globorotalites, Gavelinella, Cibicides, Heterolepa Anomalinoides, Chilostomella, Valvulineria, Pullenia, Cibicidoides, Karreria, Alabamina, Anomalina.*	Shallow to deep marine

Fig. 5: Genera belonging to both planktic and benthic ecologically significant forminiferal groups of the studied samples in north and south west Sinai (bathymetric interpretation after Boersma and Premoli-Silva, 1983 and Martine, 1989).

5- Planktic/Benthic (P/B) Foramini-Feral Ratio:

In the present work, this ratio is determined for each sample in the four studied sections. Then for each biozone the arithmetic mean of these ratios is calculated as a standared value characterizing the stratigraphic interval covered by the biozone **[29-32** and others**]**.

6- Arenaceous / Calcareous (A/C) Benthic Foraminiferal Ratio:

The same method of calculating P/ B ratios is followed to get the A/C ratios **[33]**.

7- Benthic Genus/Genera Predo-Minance:

Poag **[34]** define this concept as the genus or genera that comprise the highest proportion of a benthic population having paleoecologic meaning.

The different values of the seven above-mentioned paleoecologic indicators in each studied section are tabulated in figures 6&7. The average values of these indicatores, for the composite logs of the studied four sections, are tabulated in the tables of figures 8& 9.

FORAMINIFERL PALEOECOLOGY

According to the statistical data represented by the previously mentioned paleoecologic indicators, the successions of the two sections of the north Sinai area were subdivided into five ecozones (Fig. 8). The succession of the other two sections (in southwest Sinai area) were subdivided into nine ecozones (Fig. 9).

The environment of each ecozone is deduced and a proposed paleobathymetric curve is drawn for the successions of the two areas (Fig. 10).

In the studied successions, five bathymetrically significant groups of foraminiferal assemblages can be recognized according to Berggren's **[31]** model:

1- Littoral assemblage (0-10 m).

It is represented only in the north Sinai area succession by the ecozones no. 1 & 4 (Fig. 8). It is characterized by very low frequency, very low percentage of heterohelicid and unkeeld planktic foraminifers, very high percentage of benthic foraminifers with predominance of nodosariid and rotaliid, very low P/B ratio, very low A/C ratio in warm conditions and the predominant benthic genera were *Nodosaria, Gavelinella and Cibicides.*

2- Inner neritic assemblage (10-30 m).

it is represented, also, in the succession of north Sinai area only by ecozone no. 2 (Fig. 8). It is characterized by low frequency, low percentage of unkeeled planktic foraminifers, high percentage of benthic foraminifers with predominance of rotaliid and nodorariid, very low diversity, low P/B ratio, no arenaceous benthic foraminifers and the predominant benthic genera were *Cibicides and Lenticulina.*

3- Middle Neritic Assemblage (30 - 100 m).

it is represented in the north Sinai area succession by the ecoznoes no. 3 and 5 (Fig. 8). In southwest Sinai it is represented by ecozones no. 3 and 7

Age	Formation	*Biozone*	El Hassana section													Gebel Yellg section												
			Freq.	Planktic groups			Benthic groups					Div.	P/B	A/C	*Genera predominance*	Freq.	Planktic groups			Benthic groups					Div.	P/B	A/C	*Genera predominance*
				Het.	Keeled	Unk.	Arc.	Mil.	Nod.	Bul.	Rot.						Het.	Keeled	Unk.	Arc.	Mil.	Nod.	Bul.	Rot.				
?Ypresian	Thebes	*Morozovella formosa formosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	ESNA	*Morozovella subbotinae*	1038	-	120	900	-	-	6	5	7	9	98:02	0:100	*Eponides*	-	-	-	-	-	-	-	-	-	-	-	-	-
		Morozovella edgari	261	-	80	150	-	-	5	-	31	7	86:14	0:100	*Cibicides*	-	-	-	-	-	-	-	-	-	-	-	-	-
Thanetian		*Morozovella velascoensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	1600	-	90	200	630	-	350	110	220	14	15:85	48:52	*Clavulinoides Nodosaria Cibicides*
		Planorotalities pseudomenardii	-	-	-	-	-	-	-	-	-	-	-	-	-													
		Planorotalities pusilla pusilla	-	-	-	-	-	-	-	-	-	-	-	-	-													
		Morozovella angulata	2656	-	360	1420	-	-	545	155	176	17	67:33	0:100	*Lenticulina Cibicides*	2714	-	120	360	890	-	758	111	475	22	18:82	40:60	*Spiroplectammina Lenticulina Cibicides*
Danian		*Morozovella uncinata*	317	-	90	210	-	-	5	2	10	9	95:05	0:100	*Cibicides*	5600	-	680	2120	623	-	1225	226	726	26	50:50	22:78	*Marginulinopsis Cibicides*
		Morozovella trinidadensis	30	-	-	-	-	-	11	4	15	10	0:100	0:100	*Lenticulina Cibicides*	-	-	-	-	-	-	-	-	-	-	-	-	-
		Morozovella pseudobulloides														37	-	5	20	-	-	-	-	12	6	68:32	0:100	*Cibicides*
Maastrichtian		*Abathomphalus mayaroensis*	395	2	-	2	-	-	311	50	30	17	1:99	0:100	*Nodosaria Gavelinella*	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sudr	*Gansserina gansseri*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Globotruncana aegyptiaca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Fig. (6) Quantitative foraminiferal data obtained from the north Sinai sections.

Age	Formation	Biozone	Wadi Feiran Section													Gebel Matulla section												
			Freq.	Planktic groups			Benthic groups					Div.	P/B	A/C	Genera predominance	Freq.	Planktic groups			Benthic groups					Div.	P/B	A/C	Genera predominance
				Het.	Keeled	Unk.	Arc.	Mil.	Nod.	Bul.	Rot.						Het.	Keeled	Unk.	Arc.	Mil.	Nod.	Bul.	Rot.				
Y presian	hebes	*Morozovella formosa formosa*	14040	-	4900	5200	10	-	2000	-	1930	22	71:29	03:97	*Lenticulina* *Eponides*	2414	-	220	1410	90	-	347	47	300	14	68:32	11:89	*Lenticulina* *Eponides*
	S N A	*Morozovella subbotinae*	14700	100	5000	5900	400	-	1000	300	2000	24	77:23	11:89	*Marginulina* *Eponides*	9010	5	1400	2500	900	-	2005	370	1730	17	50:50	23:77	*Marginulina* *Eponides*
		Morozovella edgari	5950	100	1900	2000	400	10	700	140	700	15	65:35	21:79	*Lenticulina* *Cibicidoides*	5780	-	1200	3900	50	-	230	50	350	16	88:12	07:93	*Lenticulina* *Cibicidoides*
Thanetian		*Morozovella velascoensis*	6442	60	800	3140	600	2	880	120	840	18	62:38	33:67	*Zeauvigerina* *Cibicides*	5807	5	550	2500	400	2	1000	150	1200	22	53:47	15:85	*Zeauvigerina* *Cibicides*
		Planorotalities pseudomenardii	7505	-	500	3000	800	5	1600	100	1500	44	46:54	20:80	*Stillostomella* *Cibicides*	450	-	50	100	90	-	110	30	70	17	33:67	30:70	*Nodosaria* *Cibicides*
		Planorotalities pusilla pusilla	14450	-	4000	8000	400	-	900	250	900	23	70:30	16:84	*Quadrimorphina* *Cibicides*	11950	-	1600	8000	900	-	850	100	500	25	71:29	38:62	*Spiroplectammina* *Lenticulina*
		Morozovella angulata	11900	-	2000	8000	400	-	600	200	700	20	84:16	21:79	*Lenticulina* *Cibiciddes*	8500	-	1950	2300	900	-	950	700	1700	27	50:50	21:79	*Spiroplectammina* *Cibicides*
Danian		*Morozovella uncinata*	[illegible]	-	3000	12000	[illegible]	-	600	100	900	21	86:14	36:64	*Spiroplectammina* *Cibicides*	22415	-	3700	16000	275	-	580	130	1730	23	88:12	10:90	*Marginulinopsis* *Cibicides*
		Morozovella trinidadensis	13290	-	2500	9500	350	-	500	400	400	22	93:07	27:73	*Lenticulina* *Stillostomella* *Cibicides*	22400	-	900	15000	1300	-	2000	700	2500	24	71:29	20:80	*Lenticulina* *Stillostomella* *Cibicides*
		Morozovella pseudobulloides	7400	-	1000	4500	750	-	650	100	400	40	80:20	39:61	*Spiroplectammina* *Lenticulina* *Cibicides*	10568	-	18	5000	1200	-	1100	1250	2000	24	47:53	22:78	*Spiroplectammina* *Nodosaria Cibicides*
Maastichtian		*Abathomphalus mayaroensis*	10410	3500	50	950	2000	10	1500	400	2600	58	43:57	33:67	*Gaudryina* *Lagena* *Gavelinella*	2617	1400	-	35	410	-	426	80	266	30	54:46	35:65	*Gaudryina,* *Lagena* *Gavelinella*
	Sudr	*Gansserina gansseri*	9160	3500	360	3140	500	10	700	250	700	49	66:34	24:76	*Dentalina* *Gavelinella*	7940	1500	60	440	860	-	1240	1160	1680	27	38:62	17:83	*Dentalina,* *Gavelinella*
		Globotruncana aegyptiaca	11400	4000	400	3600	1400	-	1000	400	600	22	70:30	41:59	*Gaudryina* *Gavelinella*	-	-	-	-	-	-	-	-	-	-	-	-	-

Fig. (7) Quantitative foraminiferal data obtained from the southwest Sinai sections.

Age	Lithostratigraphic Units	Biozone	Thickness (in m)	Frequency	Planktic groups	Benthic groups	Diversity	P/B	A/C	Benth. genera predominance	Ecozone	Environment	Paleodepth (in m)
Ypresian	Thebes Formation	*Morozovella formosa formosa*	-	-	-	-	-	-	-	-	-	-	-
	Esna Formation	*Morozovella subbotinae*	1	520	Unkeeled	Rotaliid	5	49:51	0:100	*Eponides*	5	Middle neritic	30-100
		Morozovella edgari	3	130	Unkeeled	Rolaliid	4	43:57	0:100	*Cibicides*			
Thanetian		*Morozovella velascoensis*	7	800	Unkeeled	Arenaceous Nodosariid Rotaliid	7	08:92	24:76	*Clavulinoides* *Nodsaria* *Cibicides*	4	Littoral	0-10
		Planorotalites pseudomenardii											
		Planorotalites pusilla pusilla											
		Morozovella angulata	7	2700	Unkeeled	Nodosariid Rotaliid	20	43:57	20:80	*Lenticulina* *Cibicides*	3	Middle neritic	30-100
Danian		*Morozovella uncinata*	4	3000	Unkeeled	Nodosariid Rotaliid Arenaceous	18	50:50	11:89	*Lenticulina* *Cibicides* *Spiroplectammina*			
		Morozovella trinidadensis	8	35	Unkeeled	Rotaliid Nodosariid	8	34:66	0:100	*Lenticulina* *Cibicides*	2	Inner neritic	10-30
		Morozovella pseudobulloides											
Maastrichtian		*Abathomphalus mayaroensis*	6	200	Heterohelicid Unkeeled	Nodosariid	8	1:99	0:100	*Nodosaria* *Gavelinella*	1	Littoral	0-10
	Sudr Formation	*Gansserina gansseri*	-	-	-	-	-	-	-	-	-	-	-
		Globotruncana aegyptiaca	-	-	-	-	-	-	-	-	-	-	-

Fig. 8: Table showing the average values of the statistical data based on the used paleoecologic indicators recognized in the studied foraminferal fauna in north Sinai (El-Hassana and G. Yellg sections) and their deduced environment.

Age	Lithostratigraphic Units	Biozone	Thickness (in m)	Frequency	Planktic groups	Benthic groups	Diversity	P/B	A/C	*Benth. genera predominance*	Ecozone	Environment	Paleodepth (in m)
Ypresian	Thebes Formation	*Morozovella formosa formosa*	10	8000	Unkeeled Keeld	Nodosariid Rotaliid	8	70:30	07:93	*Lenticulina* *Eponides*	9	Outer neritic	100-200
	Esna Formation	*Morozovella subbotinae*	15	11500	Unkeeled Keeld	Nodosariid Rotaliid Arenaceous	20	64:36	17:83	*Marginulina* *Eponides*			
		Morozovella edgari	2.5	5500	Unkeeled Keeld	Nodosariid Rotaliid Arenaceous	15	77:23	14:86	*Lenticulina* *Cibicides*	8	Upper continental Slope	>200
Thanetian		*Morozovella velascoensis*	10	6000	Unkeeled	Nodosariid Rotaliid Arenaceous	20	58:42	24:76	*Zeauvigerina* *Cibicides*	7	Middle neritic	30-100
		Planorotalites pseudomenardii	3	4000	Unkeeled	Nodosariid Rotaliid Arenaceous	16	40:60	25:75	*Nodsaria* *Cibicides*			
		Planorotalites pusilla pusilla	1	13000	Unkeeled	Nodosariid Rotaliid Arenaceous	24	70:30	27:73	*Spiroplectammina* *Lenticulina* *Cibicides*	6	Outer neritic	100-200
		Morozovella angulata	3.5	10500	Unkeeled Keeld	Nodosariid Rotaliid Arenaceous	24	67:33	21:79	*Lenticulina* *Cibicides*			
Danian		*Morozovella uncinata*	1.5	15000	Unkeeled	Nodosariid Rotaliid Arenaceous	22	87:13	23:77	*Marginulina* *cibicides*	5	Upper continental slope	>200
		Morozovella trinidadensis	2.5	12500	Unkeeled	Nodosariid Rotaliid Arenaceous	23	82:18	24:76	*Stilostomella* *spiroplectammina*			
		Morozovella pseudobulloides	2.5	9000	Unkeeled	Nodosariid Rotaliid Arenaceous	32	64:36	31:69	*Nodosaria* *cibicides*	4	Outer neritic	100-200
Maastrichtian		*Abathomphalus mayaroensis*	3.5	6500	Heterohelicid	Nodosariid Rotaliid Arenaceous	44	49:51	34:66	*Gaudryim* *Lagena* *Gavelinella*	3	Middle neritic	30-100
	Sudr Formation	*Gansserina gansseri*	35	8500	Heterohelicid Unkeeled	Nodosariid Rotaliid Arenaceous	38	52:48	20:80	*Dentalina* *Gavelinella*	2	Outer neritic	100-200
		Globotruncana aegyptiaca	2	6000	Heterohelicid Unkeeled	Nodosariid Rotaliid Arenaceous	22	70:30	40:60	*Gaudryima* *Gavelinella*	1	Upper continental s0lope	>200

Fig. 9: Table showing the average values of the statistical data based on the used paleoecologic indicators recognized in the studied foraminferal fauna in north Sinai (W. Feiran and G. Matulla section) and their deduced environment.

(Fig. 9). It is charaterized by moderate frequency, moderate percentage of unkeeled planktic foraminifers and benthic nodosriid and rotaliid foraminifers, moderate diversity, moderate P/B and A/C ratios and predominance of several benthic genera as *Cibicides, Lenticulina,.... etc.*

4- Outer Neritic Assemblage (100 - 200 m).

It is represented in the succession of the southwest Sinai area only by the ecozones no. 2, 4, 6, 9, see figure 8. It is characterized by very high frequency, very high percentage of unkeeled and keeled planktic foraminifers, moderate nodosariid and rotaliid benthic foraminiferal percentage, moderatly to high diversity, high P/B and low to moderate A/C ratios and predominance of several benthic genera as *Spiroplectammina, Lenticulina, Marginulina, Eponides,* etc.

5- Upper Continental Slope Assem-Blage (> 200 m).

it is represented, also in the succession of the southwest Sinai area only, in the ecozones no. 1, 5, 8 (Fig. 9). It is characterized by moderate to high frequency, very high percentage of unkeeled and keeled planktic foraminifers, low to moderate nodosariid, and arenaceous benthic foraminiferal percentage, low to moderate diversity, very high P/B ratio, low to high A/C ratio and predominance of *Lenticulina, Marginulina, Stillostomella, Cibicides and Gavelinella* benthic genera.

PALEOBATHYMETRIC CHANGES AND TECTONIC HISTORY

The study of the vertical distribution of the previous mentioned ecozones enables to determine the vertical changes in the bathymetry of the sea and construct a bathymetric curve **[35]** for the studied successions in the north and southwest Sinai areas during Maastrichtian, Paleocence and Early Eocene time intervals (Fig. 10).

It can be noticed, from the established curves, that they agree with respect to their general shape but that they differ regarding to the absolute depths characterizing each area (Fig. 10).

The similarities of the two areas may be related to the effect of the global changes of sea level displayed in the curve of Haq *et al.* **[35]** during the Late Cretaceous and the Early Tertiary time interval.

The tectonic history of the two studied areas can be discussed separately as follows:

1- The North Sinai Area:

It began with a very shallow marine environment of deposition (Littoral) during the latest Maastrichtian time. At the end of the Maastrichtian the tectonic activity began with a transgressive movement which accompanied the K/T boundary. The effect of this movement remains until the begginning of the Paleocene. It causes the first unconformity in the area (disappearance of the *Globigerina eugubina* Zone) and changes the environment of deposition into shallow marine environment (inner

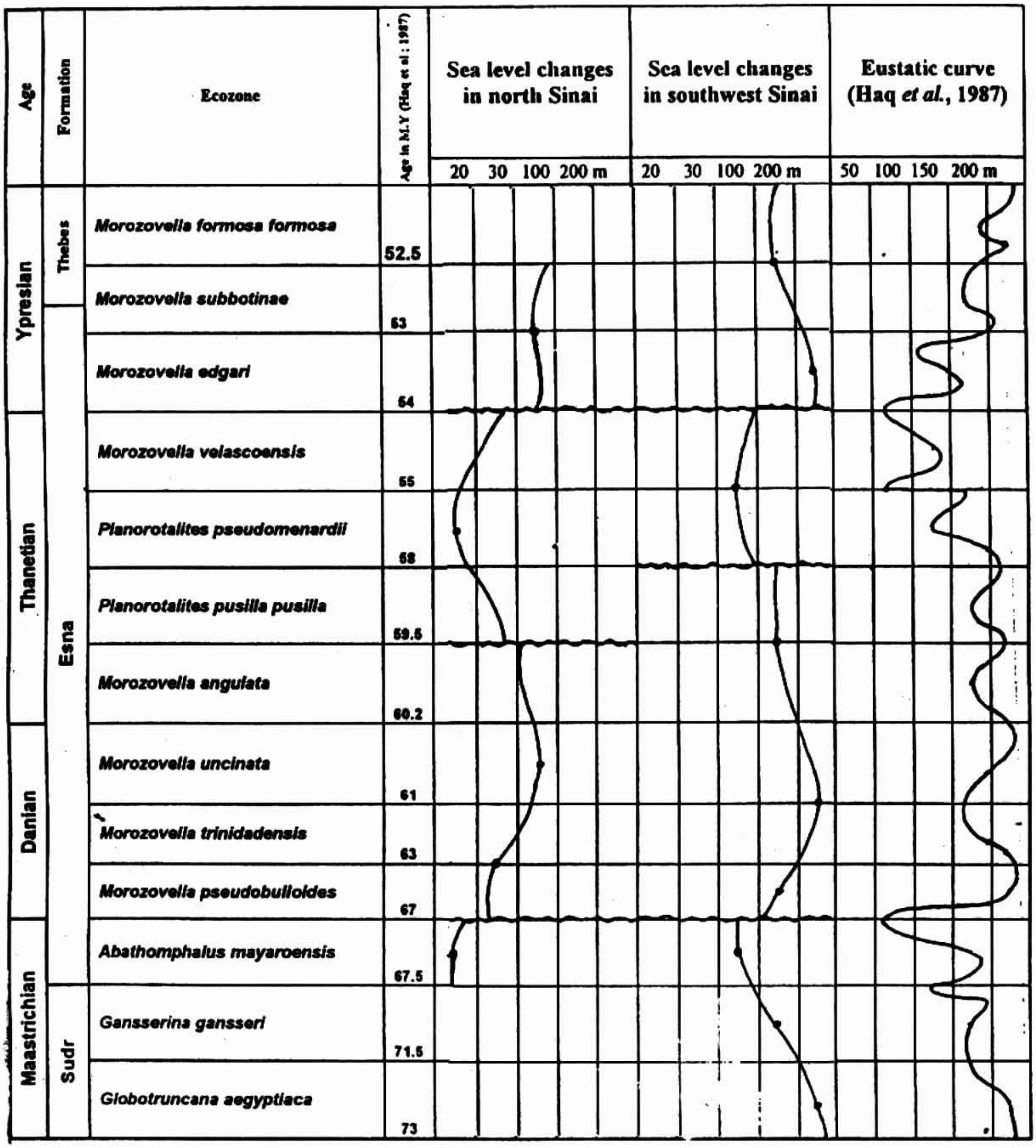

Fig. (10) Correlation between the bathymetric variations observed in north and southwest Sinai and the global eustatic curve of Haq *et al.*, (1987).

neritic) during the Early and Middle Danian and then into middle neritic during the late Danian and the Early Thanetian. This First tectonic activity acted during about 8 million years (67.5-59.5 M.Y.), see Fig. (10).

The second eustatic change in the area was a regressive movement began with the beginning of the Middle Thanetian. It caused the second unconformity (local) in the area (disappearance of the lower part of *Planorotalites pusilla pusilla* Zone) and the change of the enviroment into very shallow marine (Littoral). Its effect remains until the end of the Paleocene and tectonic activity proceeded for about 5.5 million years (59.5 54 M. y.), see Fig. (10).

The third and last eustatic change in this area was another transgressive movement which began with the end of the Paleocene. It caused the third unconformity which is local, (disapperance of the uppermost part of the *Morozovella velascoensis* Zone and the lowermost part of the *Morozovella edgari* Zone) and it coincides with the Paleocene / Eocene baundary. It changes the environment into middle neritic. Its effect remained until the middle Early Eocene (Middle Ypresian) and tectonic activity proceeded for about 1.5 milliom years (54-52.5 M.Y.), see Fig. (10).

2- The southwest Sinai area:

Tectonic activity during the studied time span began in the Early Maastrichtian with a gradual regressive movement. It changed the environment of deposition from upper continental slope environment to outer neritic to middle neritic during the Late Maastrichtian. At the end of the Maastrichtian the tectonic movement was changed into the strong transgressive one charac-terized the **K** / T baundary. This first tectonic activity proceeded for about seven million years (73-67 M. Y.), see Fig. (10).

The Paleocene time began with the disappearance of the earliest Paleocene time (the period of *Globigerina eugubina* Zone) according to the action of the tectonic activity at the K/T boundary. It caused the first unconformity (regional) in this area.

The second eustatic change began with very slight and gradual transgressive movement followed by very slight and gradual regressive movement. It changed the enviroment of deposition from outer neritic to upper continental slope during the time interval of middle Early Paleocene to early Late Paleocene. This phase ended with the second unconformity (local) in the area which was represented by the disappearance of the topmost of the lower part of middle Late Paleocene and the lowermost of the upper part of middle Late Paleoene time (the period of the top part of the *Planorotalites pusilla pusilla* Zone and the base part of *Planorotalites pseudomenardii* Zone). The second tectonic activity spanned about 9 million years (67-58 M. a.), see Fig. (10).

The third eustatic change began with gradual transgressive movement. It changed the environment of deposition from inner neritic to middle neritic. It took place during the time interval from the upper part of middle Late Paleocene to the late Late Paleocene. This eustatic change ended with the third unconformity which was represented with the disappearance of the topmost part of the Late Paleocene and the lowermost part of the Early Eocene (the period of the uppermost part of the *Morozovella velascoensis* Zone to the lowermost part of the *Morozovella edgari* Zone) which represents the Paleocene/Eocene boundary. It acted for about 4 million year (58-54 M.a.), see Fig. (10).

The fourth eustatic change was a gradual regressive movement. It changed the environment of deposition from upper continental slope to outer neritic during the time interval from early Early Eocene to late Early Eocene (Early to Late Ypresian). This tectonic activity spained about 2.5 million year (54-51.5 M.a.), see Fig. (10).

CONCLUSIONS

The study of the quantitative stratigraphic vertical distribution of the foraminiferal fauna of the Upper Cretaceous - Lower Paleogene succession in north and southwest Sinai areas, Egypt led to the following results.

According to statistical data on the constitution of the identified planktic and benthic foraminiferal fauna, the bathymetry and ecologic conditions of the thirteen planktic foraminiferal zones recognized in the four studied sections were deduced.

Seven paleoecologic indicators were investigated and discussed for these zones and the environment of each zone was deduced and a proposed paleoecologic bathymetric curve drawn.

Five bathymetrically significant foraminiferal assemblages were recognized following the scheme of Berggren **[31]**: (1) Littoral assemblage; (2) Inner neritic assemblage; (3) Middle neritic assemblage; (4) outer neritic assemblage; (5) upper continental slope assemblage.

The tectonic history of the areas is established. It suggests that the area of north Sinai was subjected to three eustatic changes and the area of southwest Sinai to four.

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